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**Marshall Islands Program
Quality Assurance Report**

**Performance Evaluation of Whole
Body Counting Facilities in the
Marshall Islands (2002-2005)**

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February 2007

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Table of Contents

Introduction	01
Results and Discussion.....	02
Summary	04
References	04
Acknowledgments	04
Appendix A. Summary performance evaluation statistical data and charts for whole body count measurements performed at the LLNL, Enewetak, Rongelap and Utrök (Majuro) Atoll whole body counting facilities used in support of the Marshall Islands Radiological Surveillance Program (2002–2005). -----	
	A-1

List of Tables

Table 1a. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the LLNL facility (2002–2005)	05
Table 1b. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Enewetak facility (2002–2005)	06
Table 1c. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Rongelap facility (2002–2005)	07
Table 1d. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Utrök (Majuro) facility (2002–2005) ---	08

List of Figures

Figure 1. Multivar chart expressed as the relative bias statistic for whole body count measurements of ^{137}Cs in performance evaluation samples supplied by the Oak Ridge National Laboratory (2002–2005)	09
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Performance Evaluation of Whole Body Count Measurements Performed by Participants under the Marshall Islands Radiological Surveillance Program (2002-2005)

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Introduction

The United States Department of Energy (U.S. DOE) has recently implemented a series of strategic initiatives to address long-term radiological surveillance needs at former U.S. nuclear test sites in the Marshall Islands (<https://eed.llnl.gov/mi/>). Local atoll governments have been actively engaged in developing shared responsibilities for protecting the health and safety of resettled and resettling population at risk from exposure to elevated levels of residual fallout contamination in the environment. Under the program, whole body counting facilities have been established at three locations in the Marshall Islands. These facilities are operated and maintained by Marshallese technicians with scientists from the Lawrence Livermore National Laboratory (LLNL) providing technical support services including data quality assurance and performance testing. We have also established a *mirror* whole body counting facility at the Lawrence Livermore National Laboratory as a technician training center. The LLNL facility also allows program managers to develop quality assurance and operational procedures, and test equipment and corrective actions prior to deployment at remote stations in the Marshall Islands.

This document summarizes the results of external performance evaluation exercises conducted at each of the facilities (2002-2005) under the umbrella of the Oak Ridge National Laboratory Intercomparison Studies Program (ISP). The ISP was specifically designed to meet intercomparison requirements of the United States (U.S.) Department of Energy Laboratory Accreditation Program (DOELAP). In this way, the Marshall Islands Radiological Surveillance Program has attempted to establish quality assurance measures in whole body counting that are consistent with standard requirements used to monitor DOE workers in the United States. Based on ANSI N13.30, the acceptable performance criteria for relative measurement bias and

precision for radiobioassay service laboratory quality control, performance evaluation, and accreditation is -25% to +50% and less than or equal to 40%, respectively.

Results and Discussion

LLNL receives performance evaluation samples from the Oak Ridge National Laboratory on a bi-annual basis. The performance evaluation samples are prepared in a mock-up geometry (i.e., a 5-bottle phantom) that simulates the upper and lower torso of the human body. The samples usually contain a mix of barium-133 (^{133}Ba), cobalt-60 (^{60}Co), cesium-137 (^{137}Cs) and yttrium-88 (^{88}Y) isotopes at nominal concentrations of ≤ 500 nCi (18.5 kBq) per sample. The ISP at Oak Ridge use stock isotope solutions indirectly traceable to the National Institute of Standards and Technology (NIST). Details concerning the NIST stock solutions and ISP spikes used in the preparation of the 5-bottle whole body count performance evaluation samples can be found elsewhere (ISP Report, 2005 and related publications). The primary pathway for exposure to residual fallout contamination in the Marshall Islands is ingestion, especially in relation to the uptake of ^{137}Cs and, to a lesser extent, strontium-90 (^{90}Sr) from consumption of locally grown food crop products such as coconuts. Consequently, we have limited the focus of our performance evaluation exercises under the Marshall Islands Program to whole body count measurements of ^{137}Cs .

The individual results of performance evaluation exercises conducted between 2002 and 2005 (N=7) are shown in the charts presented in Appendix 1 and summarized in Table 1a-d. The relative performance of whole body counting facilities has also been represented graphically in a Multivar quality control chart (Figure 1).

For testing purposes, the relative bias (% , B_{ri}) for the i^{th} measurement conducted in a facility shows how close the measured activity (A_i) is to the actual spike value (A_{ai}), and is defined as;

$$B_{ri} = \frac{(A_i - A_{ai})}{A_{ai}} \times 100$$

The relative bias (% , B_r) for any whole body count facility is calculated as the average of the individual relative biases B_{ri} , and is defined as;

$$B_r = \sum_{i=1}^n \frac{B_{ri}}{N}$$

where N is the number of test measurements performed within each facility. The acceptance criteria for the relative measurement bias statistic based on the ANSI 13.30 standard for radiobioassay service laboratory quality control, performance testing, and accreditation is -25% to +50%.

All whole body counting facilities operating under the Marshall Islands Radiological Surveillance Program passed the bias performance test criteria for all exercises conducted during this performance evaluation period (Table 1a-d). The mean relative bias statistic for the LLNL, Rongelap, Enewetak and Utrök (Majuro) facilities over performance evaluation period was 25%, 15.4%, 19.6% and -5.4%, respectively.

The relative precision (% , S_B) of the measurements performed across each whole body count facility is the relative dispersion of the values of B_{ri} from their mean B_r , and is defined as;

$$S_B = \sqrt{\frac{\sum_{i=1}^N (B_{ri} - B_r)^2}{(N - 1)}}$$

The acceptance criteria for the relative measurement precision statistic (S_B) based on the ANSI 13.30 standard for radiobioassay service laboratory quality control, performance testing, and accreditation is less than or equal to 40%.

All whole body counting facilities operating under the Marshall Islands Radiological Surveillance Program passed the relative precision performance test criteria for all exercises conducted during this performance evaluation period (Table 1a-d). The mean relative precision statistic for the LLNL, Rongelap, Enewetak and Utrök (Majuro) facilities over this performance evaluation period was 8.9%, 1.6%, 9.5% and 16.7%, respectively.

The combined relative bias and relative precision statistic for all measurements was 12.6% and 20.5%, respectively.

Summary

During this performance evaluation period (2002-2005), the Marshall Islands whole body counting program passed all applicable ANSI N13.30 performance criteria for relative measurement bias and precision for measurements of ^{137}Cs in performance evaluations samples prepared and distributed by the Oak Ridge National Laboratory.

References

ISP (2005), Annual Performance Evaluation 2005 Whole Body Count, Intercomparison Studies Program (ISP), Oak Ridge National Laboratory, Oak Ridge, Tennessee.

HPS N13.30-1996 (1996), Performance Criteria for Radioassay, Health Physics Society, McLean, VA, 112 pp.

DOELAP (1995), Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems, DOE-STD-1095-95, U.S. Department of Energy, Washington, D.C.

Acknowledgments

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Table 1a. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the LLNL facility (2002–2005).

Facility/Date	Reference Value, nCi ($\pm 1\sigma$)	Reported Value, nCi ($\pm 1\sigma$)	Measurement Bias (%)	ANSI N13.30 Performance Evaluation Criteria (Pass or Fail)
<u>LLNL</u>				
4th Quarter 2002	291 \pm 8	396 \pm 25	36.2%	Pass
2nd Quarter 2003	123 \pm 3	158 \pm 12	28.2%	Pass
4th Quarter 2003	332 \pm 9	440 \pm 27	32.6%	Pass
2nd Quarter 2004	401 \pm 3	517 \pm 24	29.0%	Pass
4th Quarter 2004	253 \pm 7	325 \pm 15	28.5%	Pass
1st Quarter 2005	250 \pm 7	300 \pm 58	20.6%	Pass
4th Quarter 2005	75 \pm 2	83 \pm 5	11.0%	Pass
Mean Measurement Bias Statistic (all values) =			25.0%	Pass
Mean Measurement Precision Statistic (all values) =			8.9%	Pass

Table 1b. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Enewetak facility (2002–2005).

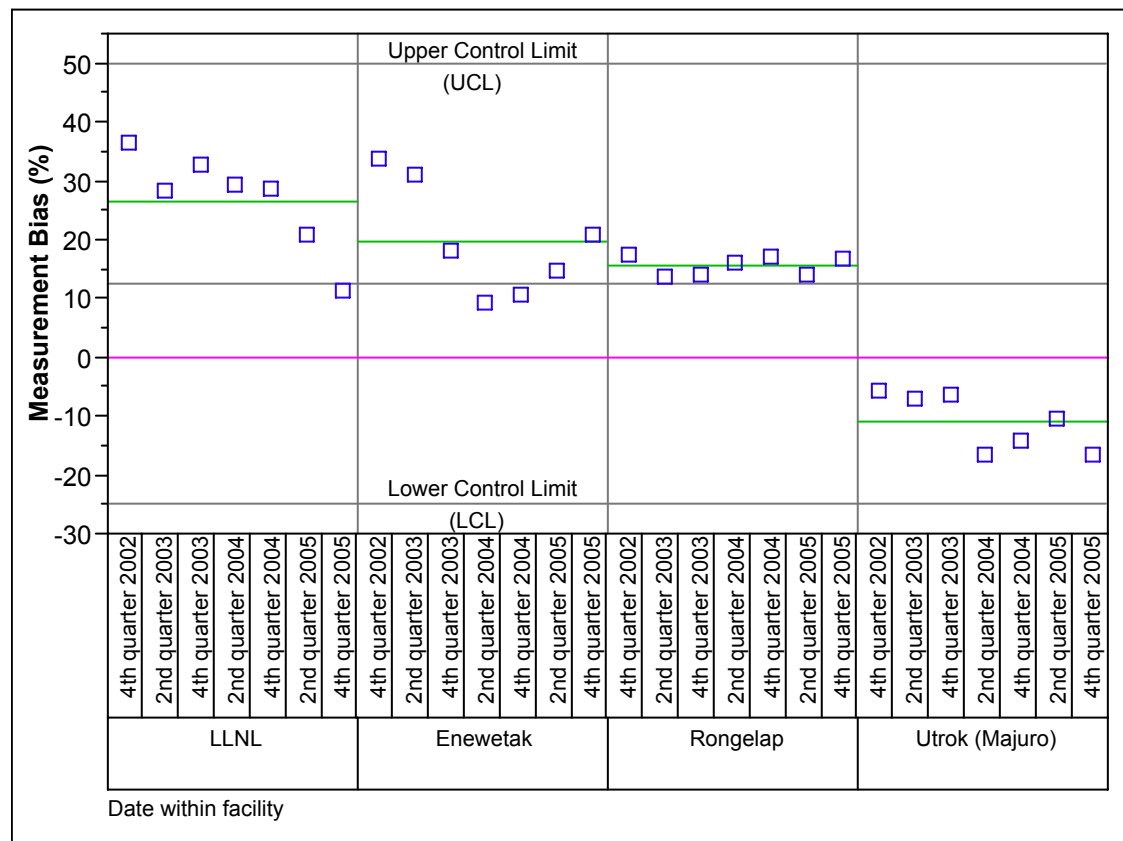
Facility/Date	Reference Value, nCi ($\pm 1\sigma$)	Reported Value, nCi ($\pm 1\sigma$)	Measurement Bias (%)	ANSI N13.30 Performance Evaluation Criteria (Pass or Fail)
<u>Enewetak</u>				
4th Quarter 2002	291 \pm 8	389 \pm 11	33.6%	Pass
2nd Quarter 2003	123 \pm 3	161 \pm 5	31.0%	Pass
4th Quarter 2003	332 \pm 9	391 \pm 11	17.9%	Pass
2nd Quarter 2004	401 \pm 3	438 \pm 12	9.2%	Pass
4th Quarter 2004	253 \pm 7	280 \pm 8	10.6%	Pass
1st Quarter 2005	250 \pm 7	286 \pm 9	14.5%	Pass
4th Quarter 2005	75 \pm 2	90 \pm 4	20.7%	Pass
Mean Measurement Bias Statistic (all values) =			19.0%	Pass
Mean Measurement Precision Statistic (all values) =			9.5%	Pass

Table 1c. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Rongelap facility (2002–2005).

Facility/Date	Reference Value, nCi ($\pm 1\sigma$)	Reported Value, nCi ($\pm 1\sigma$)	Measurement Bias (%)	ANSI N13.30 Performance Evaluation Criteria (Pass or Fail)
<u>LLNL</u>				
4th Quarter 2002	291 \pm 8	396 \pm 25	36.2%	Pass
2nd Quarter 2003	123 \pm 3	158 \pm 12	28.2%	Pass
4th Quarter 2003	332 \pm 9	440 \pm 27	32.6%	Pass
2nd Quarter 2004	401 \pm 3	517 \pm 24	29.0%	Pass
4th Quarter 2004	253 \pm 7	325 \pm 15	28.5%	Pass
1st Quarter 2005	250 \pm 7	300 \pm 58	20.6%	Pass
4th Quarter 2005	75 \pm 2	83 \pm 5	11.0%	Pass
Mean Measurement Bias Statistic (all values) =			25.0%	Pass
Mean Measurement Precision Statistic (all values) =			8.9%	Pass

Table 1d. Performance evaluation summary statistics for whole body count measurements of ^{137}Cs performed at the Utrök (Majuro) facility (2002–2005).

Facility/Date	Reference Value, nCi ($\pm 1\sigma$)	Reported Value, nCi ($\pm 1\sigma$)	Measurement Bias (%)	ANSI N13.30 Performance Evaluation Criteria (Pass or Fail)
<u>Utrök (Majuro)</u>				
4th Quarter 2002	291 \pm 8	274 \pm 10	-6.0%	Pass
2nd Quarter 2003	123 \pm 3	114 \pm 5	-7.1%	Pass
4th Quarter 2003	332 \pm 9	311 \pm 11	-6.4%	Pass
2nd Quarter 2004	401 \pm 3	333 \pm 12	-16.9%	Pass
4th Quarter 2004	253 \pm 7	217 \pm 8	-14.3%	Pass
1st Quarter 2005	250 \pm 7	223 \pm 9	-10.6%	Pass
4th Quarter 2005	75 \pm 2	62 \pm 4	-16.6%	Pass
Mean Measurement Bias Statistic (all values) =			-5.4%	Pass
Mean Measurement Precision Statistic (all values) =			16.7%	Pass



[Statistical reference lines include the null value (---); UCL (Upper Control Limit) = 50% (---); UCL (Lower Control Limit) = -25% (---); individual facility mean (—); and the overall or combined facility mean (----)]

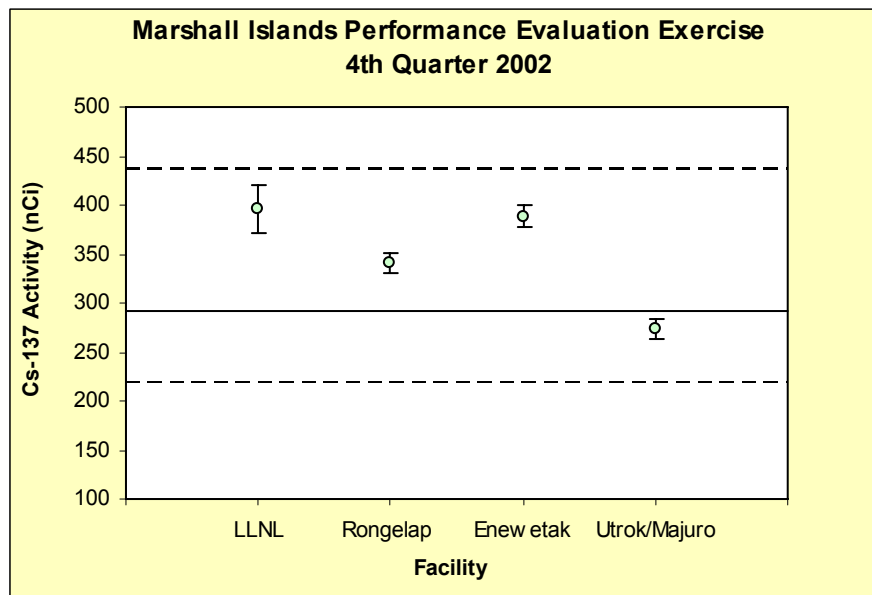
Figure 1. Multivar chart expressed as the relative bias statistic for whole body count measurements of ^{137}Cs in performance evaluation samples supplied by the Oak Ridge National Laboratory (2002–2005).

Appendix A

Summary performance evaluation statistical data and charts for whole body count measurements performed at the LLNL, Enewetak, Rongelap and Utrōk (Majuro) Atoll whole body counting facilities used in support of the Marshall Islands Radiological Surveillance Program (2002–2005)

Performance Evaluation Data (4th Quarter 2002)

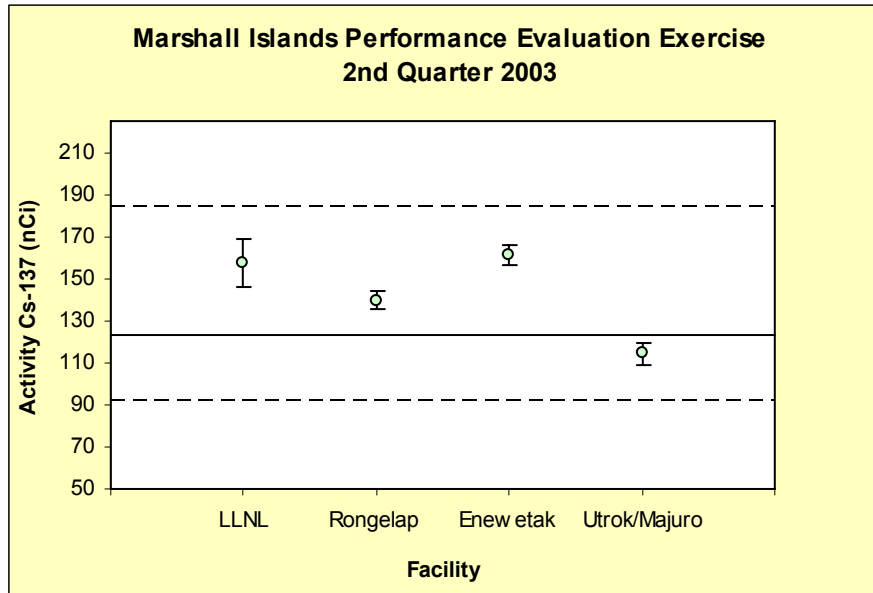
Whole Body Count Measurements of ^{137}Cs



Number of participating facility	4
Number of reported results	4
Reference value	291 nCi
Facility Mean	350 nCi
Standard Deviation	56 nCi
Standard Error Mean	28 nCi
95% Confidence Interval	260-439 nCi

Performance Evaluation Data (2nd Quarter 2003)

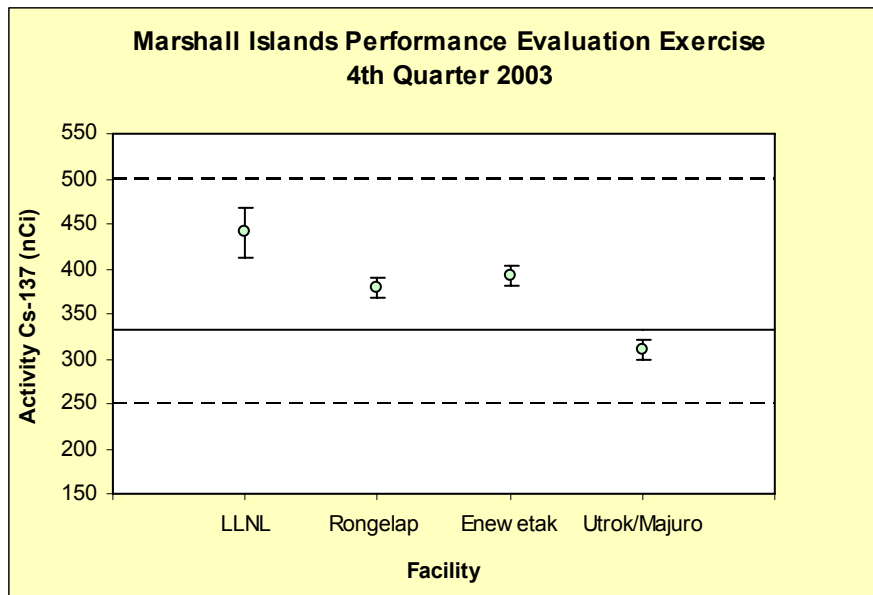
Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	123 nCi
Facility Mean	143 nCi
Facility Median	149 nCi
Standard Deviation	22 nCi
Standard Error Mean	11 nCi
95% Confidence Interval	118-184 nCi

Performance Evaluation Data (4th Quarter 2003)

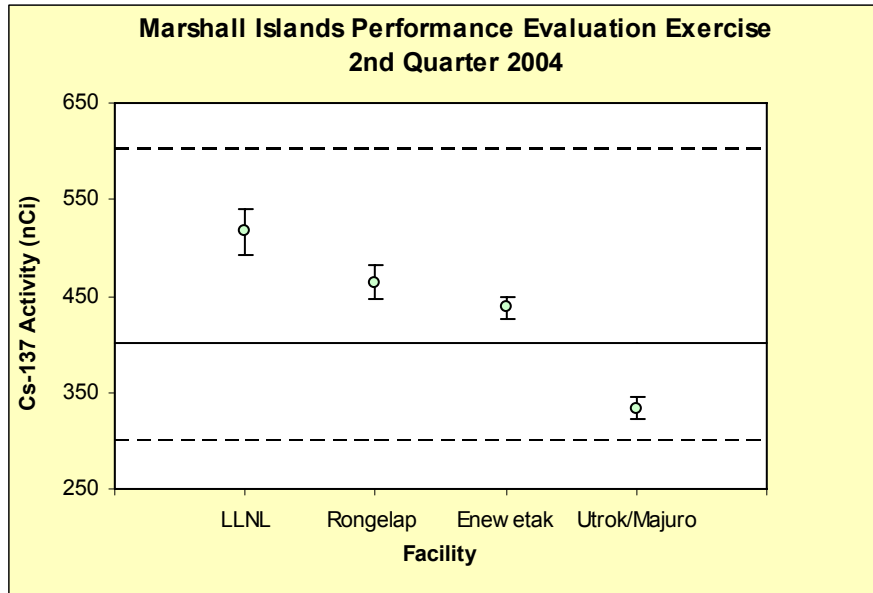
Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	332 nCi
Facility Mean	380 nCi
Facility Median	385 nCi
Standard Deviation	53 nCi
Standard Error Mean	27 nCi
95% Confidence Interval	295-465 nCi

Performance Evaluation Data (2nd Quarter 2004)

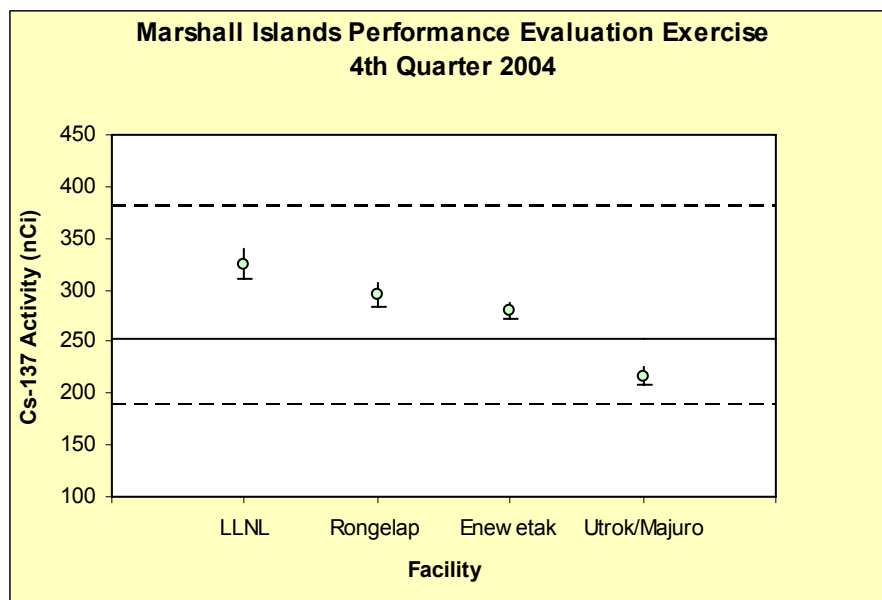
Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	401 nCi
Facility Mean	438 nCi
Facility Median	451 nCi
Standard Deviation	77 nCi
Standard Error Mean	39 nCi
95% Confidence Interval	314-561 nCi

Performance Evaluation Data (4th Quarter 2004)

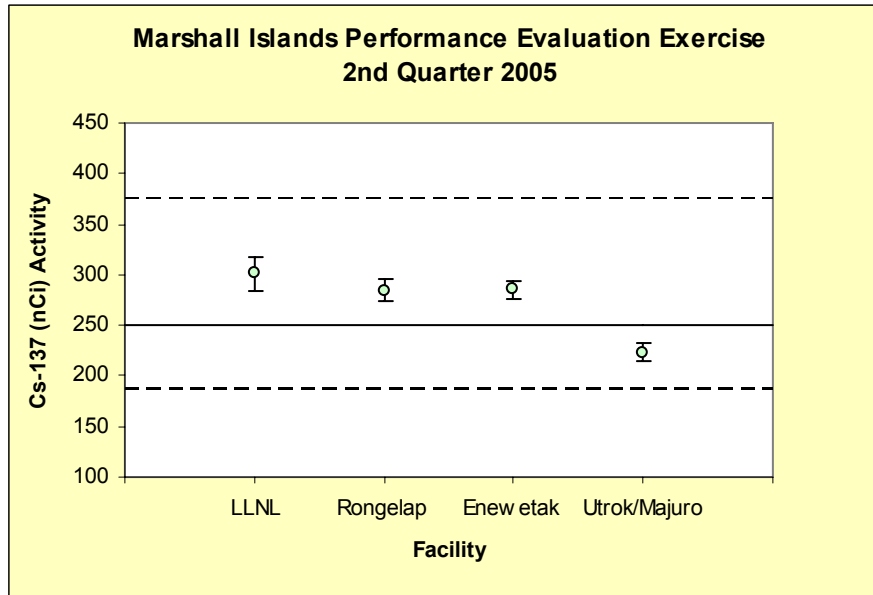
Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	253 nCi
Facility Mean	279 nCi
Facility Median	288 nCi
Standard Deviation	46 nCi
Standard Error Mean	23 nCi
95% Confidence Interval	207-352 nCi

Performance Evaluation Data (2nd Quarter 2005)

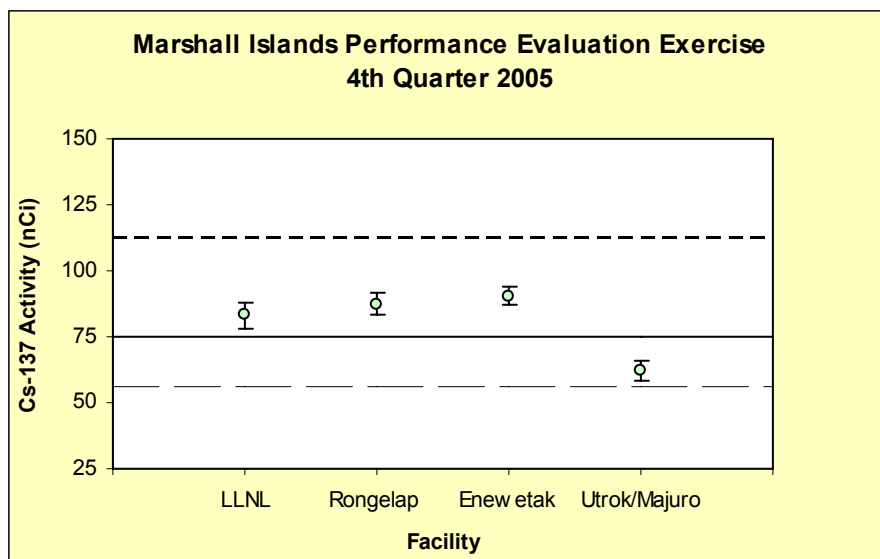
Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	250 nCi
Facility Mean	274 nCi
Facility Median	286 nCi
Standard Deviation	35 nCi
Standard Error Mean	17 nCi
95% Confidence Interval	218-329 nCi

Performance Evaluation Data (4th Quarter 2005)

Whole Body Count Measurements of ¹³⁷Cs



Number of participating facility	4
Number of reported results	4
Reference value	75.0 nCi
Facility Mean	80.5 nCi
Facility Median	85.0 nCi
Standard Deviation	12.7 nCi
Standard Error Mean	8.3 nCi
95% Confidence Interval	60.4-101 nCi.

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